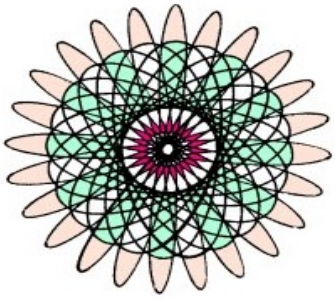

4.4 Composition, Decomposition, and Combustion Reactions

LEARNING OBJECTIVES

1. Recognize composition, decomposition, and combustion reactions.
2. Predict the products of a combustion reaction.

Three classifications of chemical reactions will be reviewed in this section. Predicting the products in some of them may be difficult, but the reactions are still easy to recognize.

A **composition reaction** (sometimes also called a *combination reaction* or a *synthesis reaction*) produces a single substance from multiple reactants. A single substance as a product is the key characteristic of the composition reaction. There may be a coefficient other than one for the substance, but if the reaction has only a single substance as a product, it can be called a composition reaction. In the reaction

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(\ell)$$

water is produced from hydrogen and oxygen. Although there are two molecules of water being produced, there is only one substance—water—as a product. So this is a composition reaction.

A **decomposition reaction** starts from a single substance and produces more than one substance; that is, it decomposes. One substance as a reactant and more than one substance as the products is the key characteristic of a decomposition reaction. For example, in the decomposition of sodium hydrogen carbonate (also known as sodium bicarbonate),

$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(\ell)$

sodium carbonate, carbon dioxide, and water are produced from the single substance sodium hydrogen carbonate.

Composition and decomposition reactions are difficult to predict; however, they should be easy to recognize.

EXAMPLE 9

Identify each equation as a composition reaction, a decomposition reaction, or neither.

1. $Fe_2O_3 + 3SO_3 \rightarrow Fe_2(SO_4)_3$
2. $NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$
3. $(NH_4)_2Cr_2O_7 \rightarrow Cr_2O_3 + 4H_2O + N_2$

Solution

1. In this equation, two substances combine to make a single substance. This is a composition reaction.
2. Two different substances react to make two new substances. This does not fit the definition of either a composition reaction or a decomposition reaction, so it is neither. In fact, you may recognize this as a double-replacement reaction.
3. A single substance reacts to make multiple substances. This is a decomposition reaction.

Test Yourself

Identify the equation as a composition reaction, a decomposition reaction, or neither.

$$C_3H_8 \rightarrow C_3H_4 + 2H_2$$

Answer

decomposition

A **combustion reaction** occurs when a reactant combines with oxygen, many times from the atmosphere, to produce oxides of all other elements as products; any nitrogen in the reactant is converted to elemental nitrogen, N_2. Many reactants, called *fuels*, contain mostly carbon and hydrogen atoms, reacting with oxygen to produce CO_2 and H_2O. For example, the balanced chemical equation for the combustion of methane, CH_4, is as follows:

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Kerosene can be approximated with the formula $C_{12}H_{26}$, and its combustion equation is

$$2C_{12}H_{26} + 37O_2 \rightarrow 24CO_2 + 26H_2O$$

Sometimes fuels contain oxygen atoms, which must be counted when balancing the chemical equation. One common fuel is ethanol, C_2H_5OH, whose combustion equation is

$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

If nitrogen is present in the original fuel, it is converted to N_2, not to a nitrogen-oxygen compound. Thus, for the combustion of the fuel dinitroethylene, whose formula is $C_2H_2N_2O_4$, we have

$$2C_2H_2N_2O_4 + O_2 \rightarrow 4CO_2 + 2H_2O + 2N_2$$

EXAMPLE 10

Complete and balance each combustion equation.

a. the combustion of propane, C_3H_8
b. the combustion of ammonia, NH_3

Solution

a. The products of the reaction are CO_2 and H_2O, so our unbalanced equation is

   $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$

   Balancing (and you may have to go back and forth a few times to balance this), we get

   $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

b. The nitrogen atoms in ammonia will react to make N_2, while the hydrogen atoms will react with O_2 to make H_2O:

   $NH_3 + O_2 \rightarrow N_2 + H_2O$

   To balance this equation without fractions (which is the convention), we get

   $4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$

Test Yourself

Complete and balance the combustion equation for cyclopropanol, C_3H_6O.

Answer

$C_3H_6O + 4O_2 \rightarrow 3CO_2 + 3H_2O$

KEY TAKEAWAYS

- A composition reaction produces a single substance from multiple reactants.
- A decomposition reaction produces multiple products from a single reactant.
- Combustion reactions are the combination of some compound with oxygen to make oxides of the other elements as products (although nitrogen atoms react to make N_2).

EXERCISES

1. Which is a composition reaction and which is not?

   a. $NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$
   b. $CaO + CO_2 \rightarrow CaCO_3$

2. Which is a composition reaction and which is not?

   a. $H_2 + Cl_2 \rightarrow 2HCl$
   b. $2HBr + Cl_2 \rightarrow 2HCl + Br_2$

3. Which is a composition reaction and which is not?

   a. $2SO_2 + O_2 \rightarrow 2SO_3$
   b. $6C + 3H_2 \rightarrow C_6H_6$

5. Which is a composition reaction and which is not?

   a. $4Na + 2C + 3O_2 \rightarrow 2Na_2CO_3$

b. $Na_2CO_3 \rightarrow Na_2O + CO_2$

6. Which is a decomposition reaction and which is not?

a. $HCl + NaOH \rightarrow NaCl + H_2O$
b. $CaCO_3 \rightarrow CaO + CO_2$

7. Which is a decomposition reaction and which is not?

a. $3O_2 \rightarrow 2O_3$
b. $2KClO_3 \rightarrow 2KCl + 3O_2$

8. Which is a decomposition reaction and which is not?

a. $Na_2O + CO_2 \rightarrow Na_2CO_3$
b. $H_2SO_3 \rightarrow H_2O + SO_2$

9. Which is a decomposition reaction and which is not?

a. $2C_7H_5N_3O_6 \rightarrow 3N_2 + 5H_2O + 7CO + 7C$
b. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$

10. Which is a combustion reaction and which is not?

a. $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$
b. $2Fe_2S_3 + 9O_2 \rightarrow 2Fe_2O_3 + 6SO_2$

11. Which is a combustion reaction and which is not?

a. $CH_4 + 2F_2 \rightarrow CF_4 + 2H_2$

b. $2H_2 + O_2 \rightarrow 2H_2O$

12. Which is a combustion reaction and which is not?

a. $P_4 + 5O_2 \rightarrow 2P_2O_5$

b. $2Al_2S_3 + 9O_2 \rightarrow 2Al_2O_3 + 6SO_2$

13. Which is a combustion reaction and which is not?

a. $C_2H_4 + O_2 \rightarrow C_2H_4O_2$

b. $C_2H_4 + Cl_2 \rightarrow C_2H_4Cl_2$

14. Is it possible for a composition reaction to also be a combustion reaction? Give an example to support your case.

15. Is it possible for a decomposition reaction to also be a combustion reaction? Give an example to support your case.

16. Complete and balance each combustion equation.

a. $C_4H_9OH + O_2 \rightarrow ?$

b. $CH_3NO_2 + O_2 \rightarrow ?$

17. Complete and balance each combustion equation.

a. $B_2H_6 + O_2 \rightarrow ?$ (The oxide of boron formed is B_2O_3.)

b. $Al_2S_3 + O_2 \rightarrow ?$ (The oxide of sulfur formed is SO_2.)

c. $Al_2S_3 + O_2 \rightarrow ?$ (The oxide of sulfur formed is SO_3.)

ANSWERS

1. a. not composition
   b. composition

3. a. composition
   b. composition

5. a. not decomposition
   b. decomposition

7. a. not decomposition
   b. decomposition

9. a. combustion
   b. combustion

11. a. combustion
    b. combustion

13. Yes; $2H_2 + O_2 \rightarrow 2H_2O$ (answers will vary)

15. a. $C_4H_9OH + 6O_2 \rightarrow 4CO_2 + 5H_2O$
    b. $4CH_3NO_2 + 3O_2 \rightarrow 4CO_2 + 6H_2O + 2N_2$